ANALYSIS OF IRREGULAR HIGH RISE STEEL BUILDING WITH AND WITHOUT FLOATING COLUMN UNDER SEISMIC FORCES

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Abstract — *The current analytical study was carried out to comprehend the behaviour of steel framed structure in the presence of mass irregularity and floating column. For this, different steel framed Structures were modelled which entails 15 storey. The plan of the building had 7 bays in both the directions i.e. X and Z direction and each bay had a span of 6m x 5m whereas, the height of each floor was taken as 3.6 m. Steel framed building was considered as commercial building, therefore all the loadings i.e. dead loads (as per IS: 875: Part-1) and live loads (as per IS: 875: Part-2) were considered in the same manner. The dynamic seismic analysis had been performed while using Response Spectrum Analysis as per requirements of the seismic code i.e.1893:2016 which states that every structure shall be designed with dynamic seismic analysis if the structure falls under seismic zone IV. In the end it can be concluded that the steel framed structure is affected with mass irregularity and floating column under dynamic seismic analysis as the forces and moments have been increased.*

Keywords— *steel framed structure, mass irregularity, and floating column.*

I. INTRODUCTION

In primitive times, the construction work was done at a very small level, just to provide shelter. These small sheltered houses were made up of mud, bamboo sticks, etc. But with the demand for more and more houses, the methods, materials, techniques required for construction change, and the revolution in the field of construction began. Since then many revolutionary structures have been erected with the utmost complex design criteria. Now, the buildings have been categorized into different kinds of structures according to their use, type of material with which the building is constructed, etc. Different complex structures such as bridges, High buildings, water structures have been constructed which has become the magnificent work of the modern world. Multipurpose structures have been constructed where shopping complexes, residential and commercial spaces co-exist.

The primary goal of the seismic analysis is to notice the behavior of the building when it is hit by earthquake forces. The ground motion, displacement of structural members, additional forces, and moments all are observed with this analysis so that the building can withstand all the additional forces and moments which are caused by the seismic. In short, Seismic analysis gives us information about the structural capacity which the structure has to attain after its erection under seismic forces. Conventionally, the seismic analysis was not considered significant but due to previous huge earthquakes throughout the world, the imperativeness of seismic analysis was recognized by everyone. Various methods were developed throughout all these years and are being used in the structure field in the modern world such as the Non-Linear method, Dynamic Method, etc. The five common seismic analysis techniques are mentioned as under:

- Simplified static coefficient method
- Response spectrum analysis
- Non-linear static pushover analysis
- Random vibration analysis
- Non-linear dynamic time domain analysis

Usually, there are two types of structures: one is regular buildings, which are also known as symmetrical buildings, and the other is irregular buildings, which are also known as unsymmetrical buildings. Regular frames of any structure are those structures that have the identical look when seen from plan or elevation. However, irregular structures are those in which arrangement in their mass, strength, stiffness, area covered, etc is not the same along with the height of the structure. adding to it, a structure with a difference between the center of mass and center of resistance is also taken as an irregular structure. Most of the time, these modern structures are constructed as irregular structures due to their architectural appearances which is an imperative demand of modern society. There exist different kinds of irregularity in various structures and they are discussed as under:

- Plan Irregularity of the building
- Vertical irregularity of the building

A floating column, also known as a hanging column or a stub column, is different from the regular column in behaviour as this column rests on a beam instead of a foundation or column. This is a kind of an additional column that is introduced in between the frame structure to give extra support to a particular beam. The presence of a floating column can be seen at any level of the building which is purely based on the requirement of the structural design. The floating column can be commonly seen in a building where the soft storey is provided as due to soft storey, the provision of providing extra space has to be considered. Thus proving large free spaces at any level simply means restricting the number of columns at that level. Therefore, to avoid having the beams of longer span at other levels, floating columns are introduced which are rested on the beam. These scenarios can be seen in residential buildings with stilt areas, industrial and commercial buildings, banquet halls with large lobbies, conference rooms, etc. floating columns are generally provided at secondary grids.

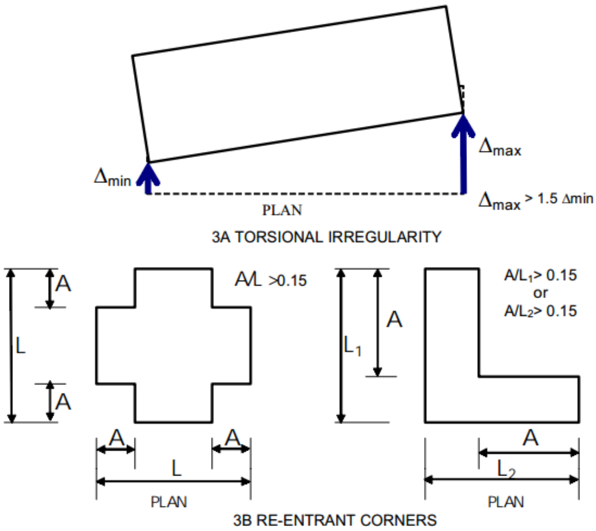

Figure 1. Example of Plan Irregularity in a Building.

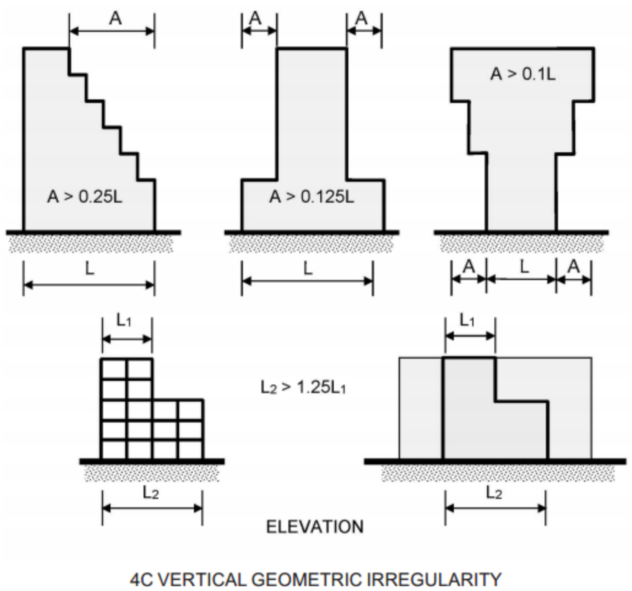

Figure 2. Example of Vertical Irregularity in a Building.

II. RESEARCH METHODLOGY

The present investigational study was conducted in different phases which had ultimately helped in achieving the present objectives of the study. There are four different phases that were entailed in research methodology and are discussed as under:

1. Phase I: Geometry of Steel Framed Structure: High rise steel framed Structures were modeled which entails 15 storey. The plan of the building had 7 bays in both the directions i.e. X and Z direction and each bay had a span of 6m x 5m whereas, the height of each floor was taken as 3.6 m. Steel framed building was considered as commercial building, therefore all the loadings i.e. dead loads (as per IS: 875: Part-1) and live loads (as per IS: 875: Part-2) were considered in the same manner.

Table: 1. Sectional Properties of Beams and Columns.

Floors	Beam size	Column size
1 to 5 floors	550 x 900 x 16 mm	600 x 600 x 16 mm
6 to 10 floors	550 x 750 x 14 mm	550 x 550 x 14 mm
11 to 15 floors	ISMB 400 with top & bottom Plates of 450 x 12 mm	450 x 450 x 14 mm

2. Phase II: Introduction of Mass Irregularity and Floating Column: Total 4 models were created as mentioned below:

i. Structure 1: 15th Storey steel building
ii. Structure 2: 15th Storey steel building with heavy mass at 5th floor
iii. Structure 3: 15th Storey steel building with heavy mass of 12th floor
iv. Structure 4: 15th Storey steel building with floating column above 12th floor

3. Phase III: Seismic Analysis as per IS: 1893: 2016: The dynamic seismic analysis had been performed while using Response Spectrum Analysis as per requirements of the seismic code i.e.1893:2016 which states that every structure shall be designed with dynamic seismic analysis if the structure falls under seismic zone IV. Structural design for earthquake is preferably performed on a probabilistic basis considering the stochastic nature of the ground motion. Rather than depending on particular ground motion record, the calculated response may be expressed in a form that can represent an envelope response of various possible ground motions. In this aspect, response spectrum analysis is the recommended method with regard to both reliability and computation efficiency, even though it is sometimes regarded as over-conservative.

4. Phase IV: Collection of Results and Comparison: After carrying out all the modelling steps in staad.pro i.e. geometry, properties, supports, load and combinations, analysis and design of the structural models was carried out. Steel code i.e. IS 800 was selected for analysis and design. Once the analysis and design of various steel framed structures having mass irregularity and floating column is done, the behaviour of various structural members (beams and columns) in terms of forces, bending moment, displacement total quantity, unit ratio etc. was recorded and maintained and represented in different forms like such as figures, tables and graphs. These results were recorded from the post-processing and output file of staad.pro.

III. **RESULTS**

RESULTS OF STEEL FRAMED STRUCTURE WITH AND WITHOUT MASS IRREGULARITY

The maximum displacement of columns at three different locations (refer fig.3.) was recorded from the staad.pro model after analyzing them under seismic response spectrum. These three locations were selected as edge, corner and central location for the column which may have different forces and moments and shows different behavior under seismic loads.

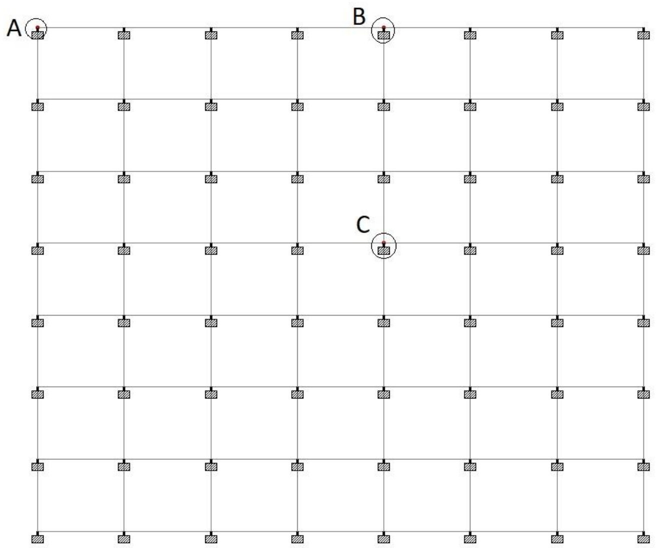

Figure 3. Location of Columns A, B and C in Plan.

Structure 1 was our base model and no irregularity was introduced in it. The results of displacement has been represented in fig 4.2 which shows that the maximum displacement of column i.e. at A, B and C locations comes out to be119.882 mm, 119.637 and 120.149 mm respectively. Structure 2 entails heavy mass as mass irregularity at 5th floor i.e. additional load of 10Kn/m2 as a floor load was introduced. The displacement of various columns i.e. A, B and C were recorded and represented in fig 4.3 and it reveals that the maximum displacement at A, B and C comes out to be 124.573 mm, 124.300 mm and 124.792 mm respectively. Structure 3 entails heavy mass as mass irregularity at 12th floor. The displacement of various columns i.e. A, B and C were recorded and represented in fig 4.4 and it shows that the maximum displacement at A, B and C comes out to be 127.496 mm, 127.208 mm and 127.689 mm respectively.

Table: 2. Maximum Displacement (mm) in Column A, B and C.

Column Location	Structure 1	Structure 2	Structure 3
A	119.882	124.573	127.496
B	119.637	124.300	127.208
C	120.149	124.792	127.689

From table: 2, it is observed that the percentage increase in maximum displacement of column when the heavy mass was placed at 5th floor (structure 2) comes out to be 4% when compared with base model (structure 1) whereas, when the same mass is shifted to the 12th floor (structure 3), then the percentage increase in maximum displacement of column comes out to be approximately 6.5% when compared with base model (structure 1).

Table: 3. Maximum Bending Moment (Kn-m) in Column A, B and C.

Column Location	Structure 1	Structure 2	Structure 3
A	448.978	466.234	466.246
B	485.627	504.980	505.042
C	485.630	504.983	505.045

From table: 3, it is revealed that the percentage increase in maximum bending moment of column when the heavy mass was placed at 5th floor (structure 2) and 12th floor (structure 3) is approximately 4% when compared with base model (structure 1).

RESULTS OF STEEL FRAMED STRUCTURE WITH AND WITHOUT FLOATING COLUMN

Structure 1 was our base model and no irregularity was introduced in it. The results of displacement has been represented in fig 4.11 which shows that the maximum displacement of column i.e. at A, B and C locations comes out to be 119.882 mm, 119.637 and 120.149 mm respectively. Structure 4 entails floating column above 12th floor. The displacement of various columns i.e. A, B and C were recorded and represented in fig 4.12 and it reveals that the maximum displacement at A, B and C comes out to be 112.546 mm, 108.178 mm and 108.737 mm respectively.

Table: 4. Maximum Displacement (mm) at A, B and C with and without floating column.

	Structure 1	Structure 4
A	119.882	112.546
B	119.637	108.173
C	120.149	108.737

Due to the presence of floating column in the structure 4 above 12th floor, the displacement is reduced up to 10% at all the location i.e. A, B and C when compared to structure 1.

In a building which has floating column, the behavior of beam beneath floating column becomes very imperative. As the load from column is transferred downwards through beam, the analysis and design of that beam becomes critical. In order to understand the behavior of those beams, the bending moment and shear force were recorded for the beams with and without floating column. The results of bending moment are represented in fig.4 and 5 for structure 1 and 4 whereas the results of shear force are shown in fig. 6 and 7.

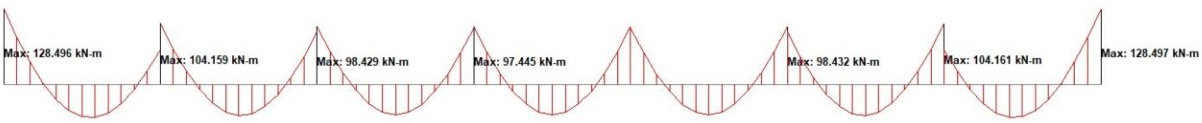

Figure 4. Bending moment of beams without Floating column in structure 1.

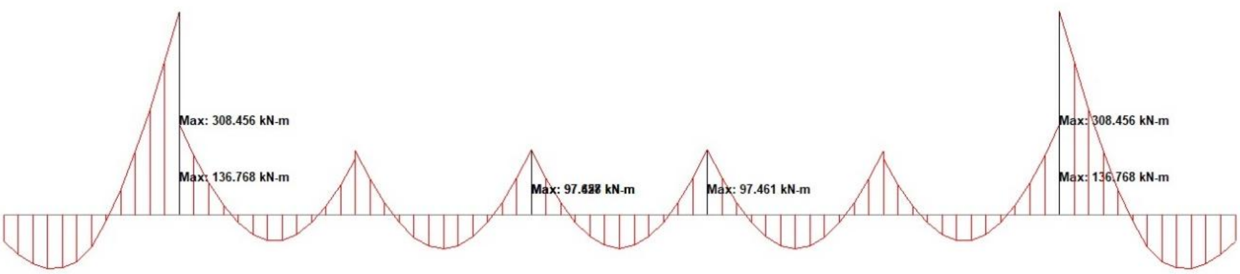

Figure 5. Bending moment of beams with Floating column in structure 4.

From fig. 4.13 and 4.14, the maximum bending moment was observed and it comes out to be 128.497 kn-m and 308.456 Kn-m for structure 1 and 4 respectively. Therefore, bending moment of edge beam under floating column increases approximately 2.5 times the bending moment of edge beam without floating column.

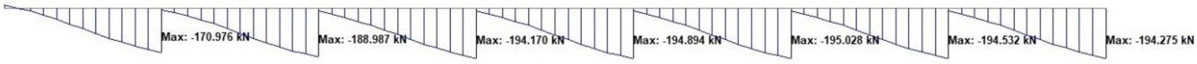

Figure 6. Shear Force of beams without Floating column in structure 1.

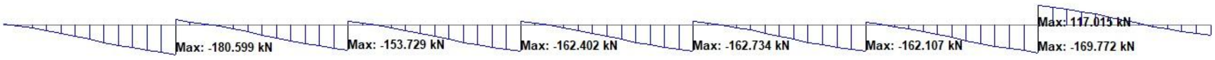

Figure 7. Shear Force of beams with Floating column in structure 4.

Table: 5. Bending Moment and Shear Force in outer beam with and without floating column.

	Structure 1	Structure 4
Bending Moment (kN-m)	128.497	308.456
Sher Force (kN)	194.275	180.599

From fig. 6 and 7, the maximum Shear Force was noted and it comes out to be 194.275 kn and 180.599 Kn for structure 1 and 4 respectively. Therefore, slight reduction of approximately 6% in shear forces was seen.

IV. Conclusions

The current study was conducted to comprehend the behavior of mass irregularity and floating column in steel framed structure. All the results were recorded and compared with each other. The conclusions which have been drawn for this study are mentioned below:

1. It is concluded that the % increase in maximum displacement of column when the heavy mass was placed at 5th floor (structure 2) comes out to be 4% when compared with base model (structure 1) whereas, when the same mass is shifted to the 12th floor (structure 3), then the % increase in maximum displacement of column comes out to be approximately 6.5% when compared with base model (structure 1).
2. It can be noted that unity ratio of all the columns is less than 1 which means that the sectional properties which were assigned to the structural members can withstand all the loads and moments without any failure.
3. It is concluded that the % increase in maximum bending moment of column when the heavy mass was placed at 5th floor (structure 2) and 12th floor (structure 3) is approximately 4% when compared with base model (structure 1).
4. Due to the presence of floating column in the structure 4 above 12th floor, the displacement is reduced up to 10% at all the location i.e. A, B and C when compared to structure 1.
5. The maximum bending moment of edge beam under floating column increases approximately 2.5 times the bending moment of edge beam without floating column. Whereas, the maximum Shear Force was slight reduced approximately 6% when floating column was introduced.

In the end it can be concluded that the steel framed structure is affected with mass irregularity and floating column under dynamic seismic analysis as the forces and moments have been increased.

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